Retrieval Stability Issues: Some Case Studies

October 21, 2003

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General Observations

- Level 2 retrieval system works well in most cases, but there are many outliers
  - Current rejection tests (residual tests and microwave vs. infrared comparisons) fail to detect bad cases.
  - Many good cases are rejected with existing tests.
  - Final retrieval amplifies the error in the bad cases.
- Retrieval appears to have instabilities.
  - Many accepted retrievals have irrational or non-physical solutions.
  - Many accepted retrievals have unexpected oscillations in product.
- Final retrieval tends to "stick" to regression first guess
  - Infrared error term significantly degrades physical retrieval's ability to alter solution.

Suspected Causes of Problems

- Residual error in microwave side-lobe correction (SLC) degrades start-up and down-stream QA.
- Cloud clearing error may be underestimated (Evan).
  - Obviously, this is true when there are problems.
  - This may be what the "error term" is trying to compensate for.
- Undetected Cirrus or Aerosol contamination.
- Undetected low cloud (*e.g.*, marine stratus) contamination.
- Microwave and Infrared "Tuning" issues.
- Product oscillations due to
  - Under-estimates of error and/or incorrect tuning.
  - A theoretical flaw in regularized SVD.
  - Unbalanced or sparse selection of channels.

Additional Diagnostics Are Needed

- The system is complex and we are only evaluating the end results of complex operators.
  - We only know some of the "truth."
  - Interaction of multiple problems is confounding.
- Early solutions to fix these issues are not robust; however, they have become quasi-permanent components of the system.
  - The error term may be the wrong thing to do (my fault).
  - Tuning used in JPL system is suboptimal
    - based on 1 training day
    - has the form of a brightness temperature bias.
  - QA using ECMWF or NCEP models may catch bad cases but they may induce a system bias towards the model.
- To make design solutions (either QA or algorithm modifications) we need to know details as to why the retrieval minimized to the wrong answer.

A New Visualization Tool

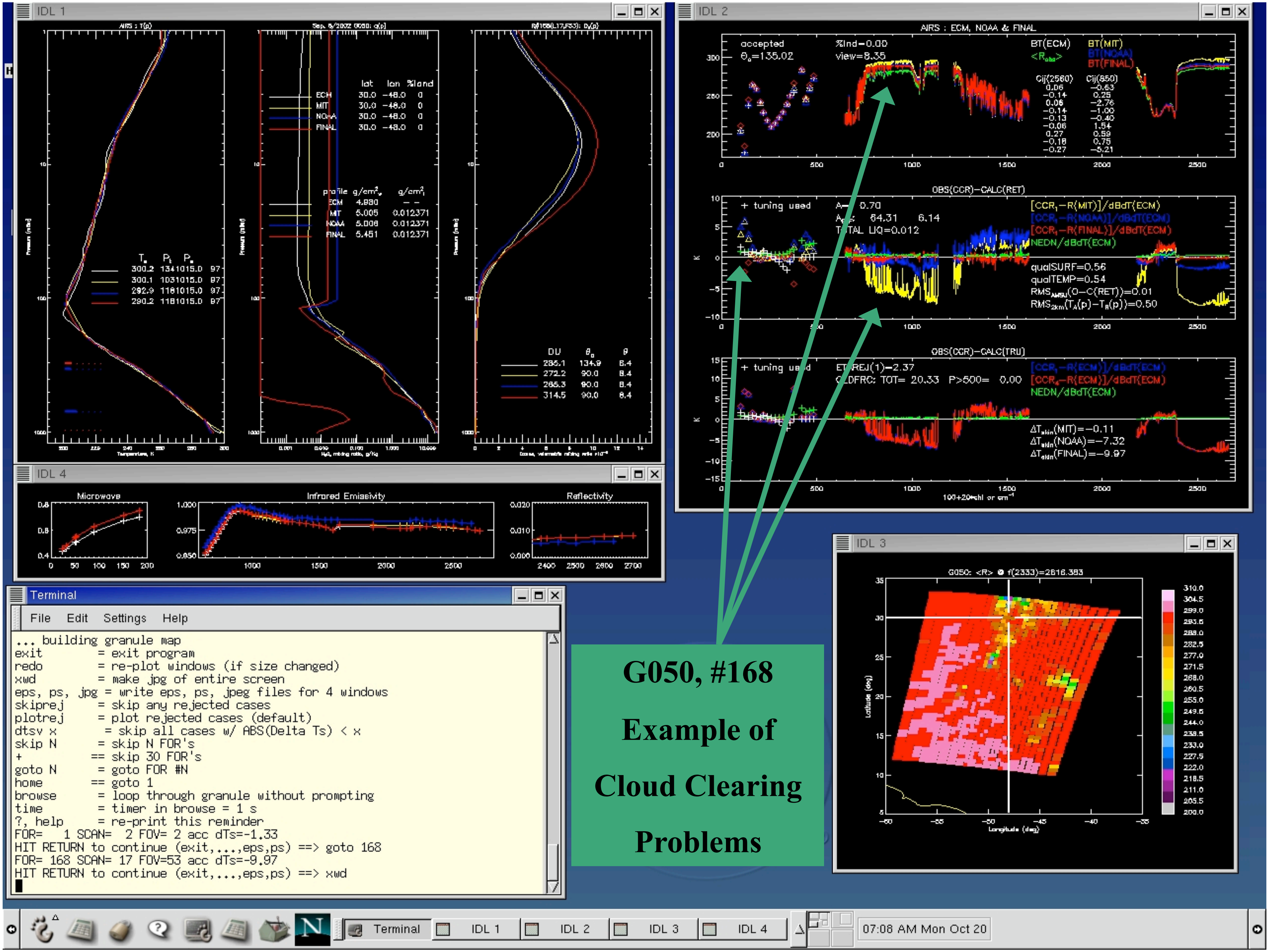
- Initial idea was stimulated by a comment Hank Revercomb made in the July net meeting.
- Assembled an interactive tool to simultaneously visualize the following items <u>for a single Golfball</u>:
  - The spatial variability of a AIRS channel within the granule.
  - T(p),q(p),O_3(p) profiles, T_{skin}, Liquid water(p), cloud heights, etc.
  - Emissivity and Reflectivity Products.
  - <R>, R(MIT), R(NOAA), R(FINAL), R(ECMWF) for ALL chl's.
  - CCR_1-R(MIT), CCR_1-R(NOAA), CCR_4-R(FINAL) for ALL chl's,
  - CCR_1-R(ECMWF), CCR_4-R(ECMWF)
  - C_{ij}, glint, QA, and L2 rejection indicators are on figures.
- <u>This tool is evolving rapidly</u>.

Another Diagnostic Tool

- Ability to simulate radiances from real AIRS products.
  - EASILY and QUICKLY build a L2 "truth" granule from ECMWF and retrieval any product file(s). Currently,
    - take T(p),q(p) from ECMWF
    - all other state parameters from the FINAL retrieval.
  - EASILY and QUICKLY simulate AIRS/AMSU/HSB L1b granules from the L2 "truth" granules.
- Retrieval system and all diagnostic tools operate on these simulated granules.
  - Can compare statisical error characteristics of real data and simulated data.
  - Can visualize individual Golfball's.

Summary of Example Cases Shown on the next 6 pages

Sep. 6, 2002	ΔT_s	Comments	Class of Problem
G050 #168	-11.0	Ocean ,night 18% cloudiness	Cloud Clearing
G034 #254	-8.3	Ocean, night SW ε(v) droops	Aerosol?
G017 #187 (real & SIM)	?	Desert, night Emissivity Issues	Land Emissivity
G100 #596	-1.2	Ocean, Night Looks good, BUT	Cirrus?
G159, #701	+0.6	Reflectivity OK Looks good, BUT	Glint, Emissivity?

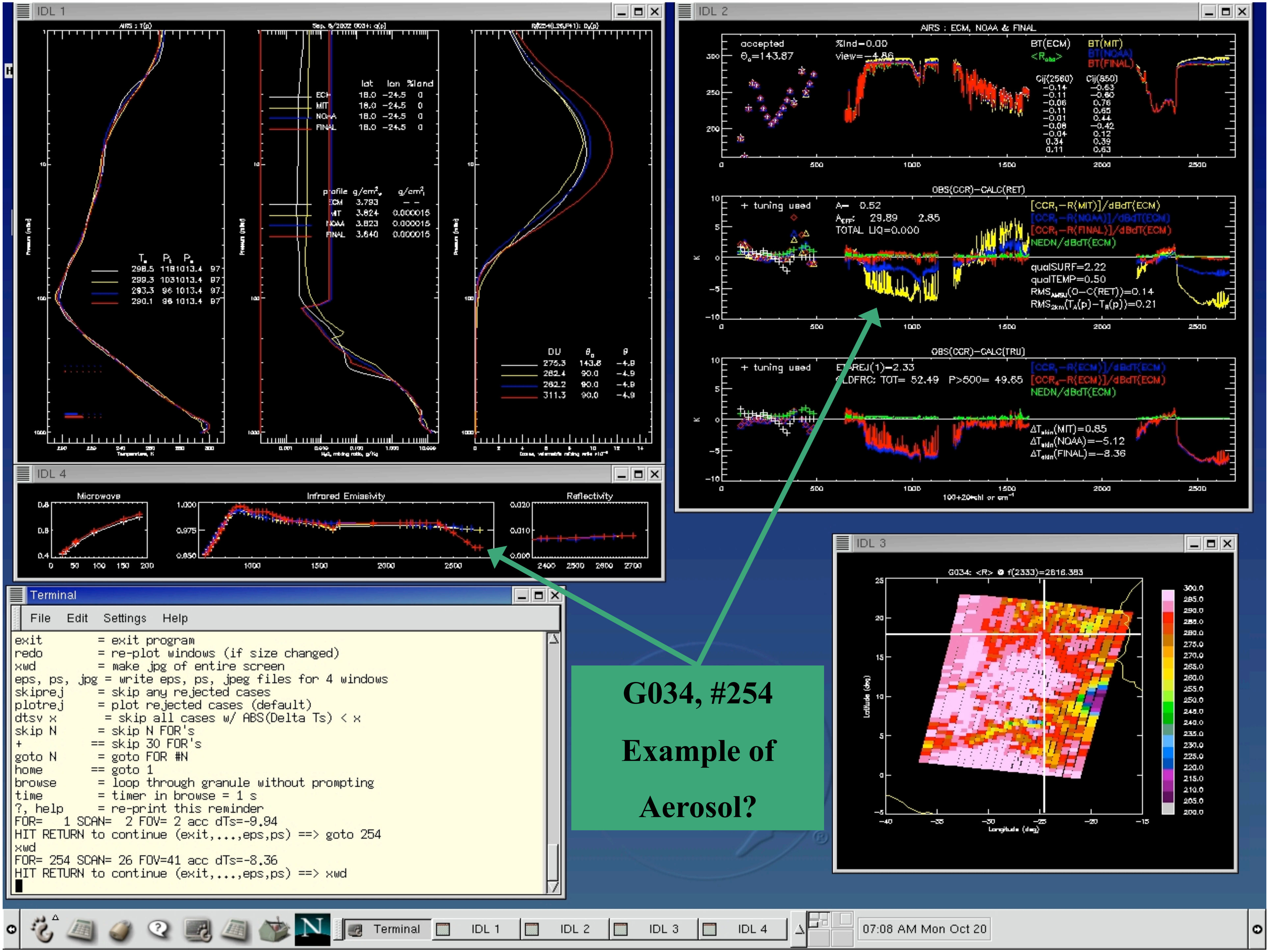


G050, #168

Example of

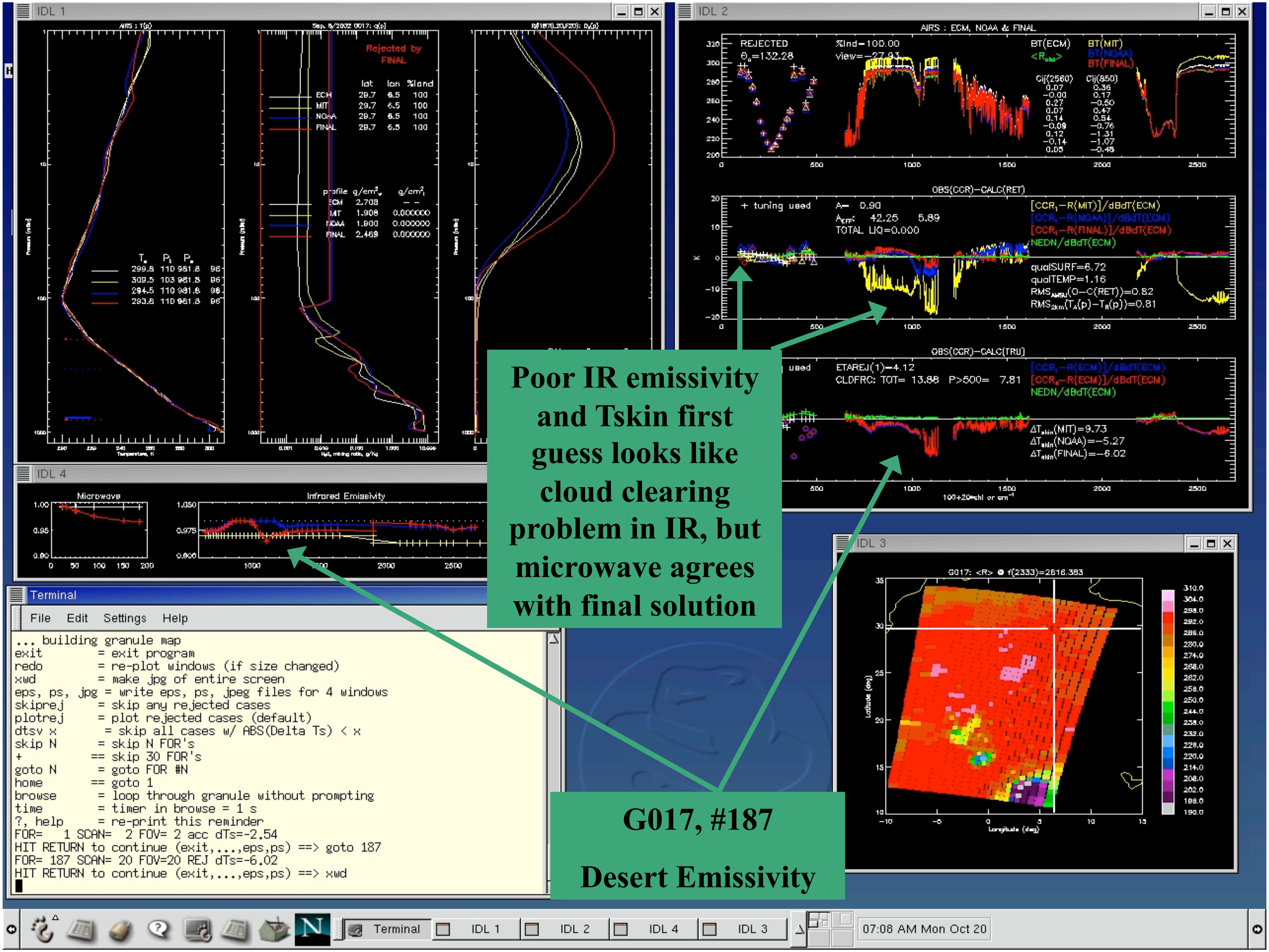
Cloud Clearing

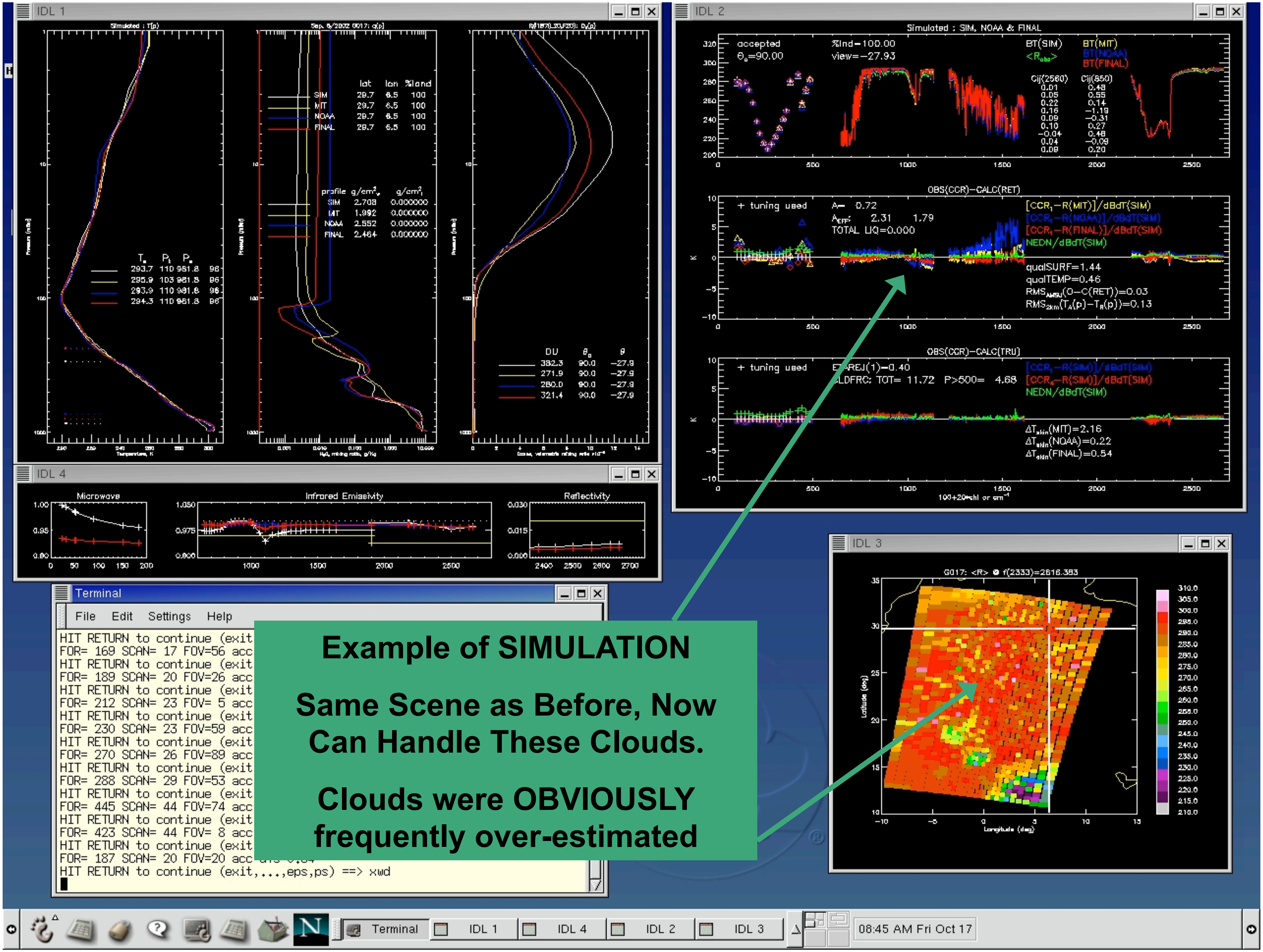
Problems



G034, #254

Example of Aerosol?

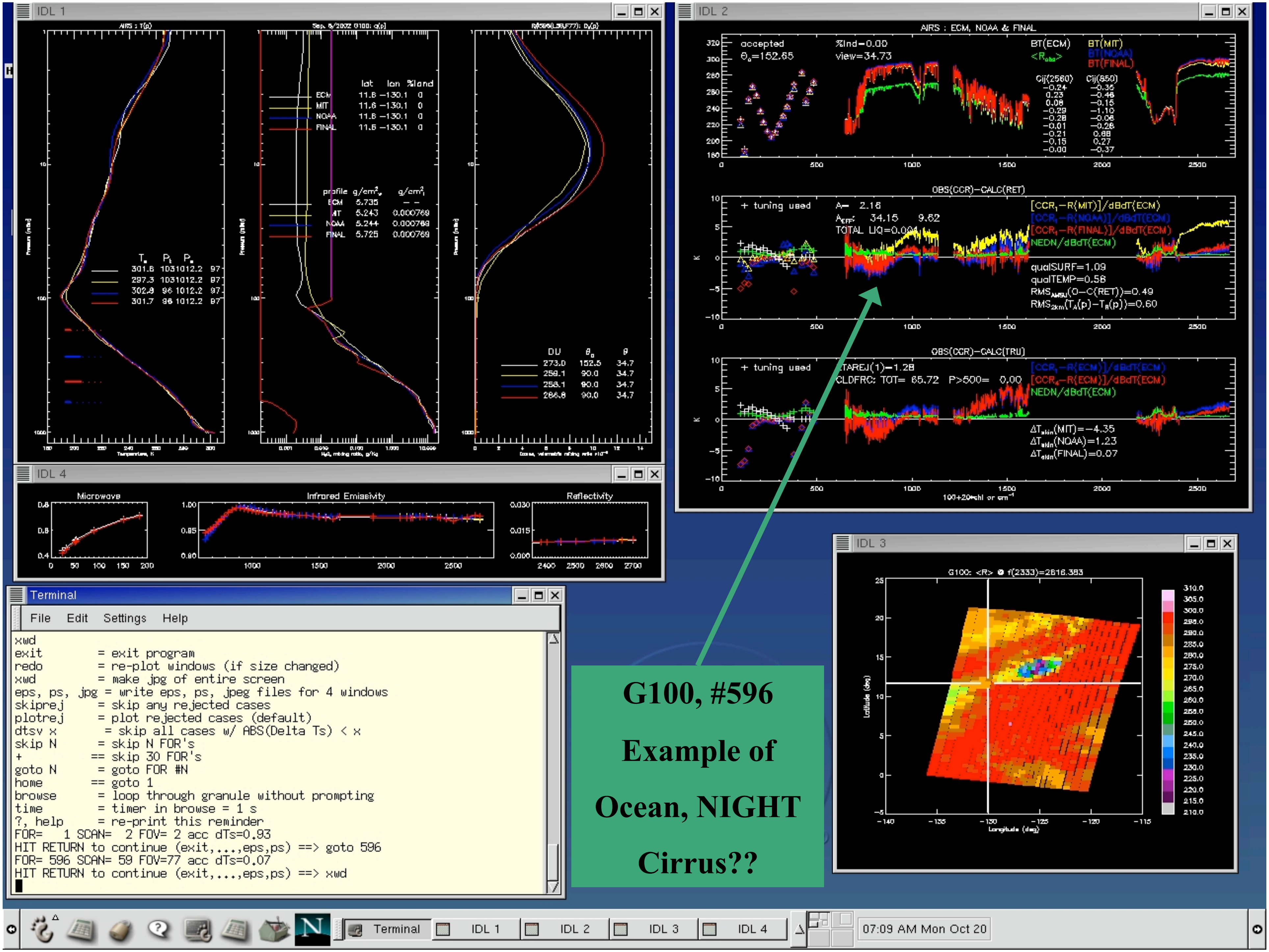

Poor IR emissivity and Tskin first guess looks like cloud clearing problem in IR, but microwave agrees with final solution
G017, #187
Desert Emissivity
IDL 1
IDL 2
IDL 3
IDL 4
AIRS : ECM, NOAA & FINAL
OBS(CCR)−CALC(RET)
OBS(CCR)−CALC(TRU)
Microwave
Infrared Emissivity
Terminal
File Edit Settings Help
... building granule map
exit = exit program
redo = re-plot windows (if size changed)
xwd = make jpg of entire screen
eps, ps, jpg = write eps, ps, jpeg files for 4 windows
skiprej = skip any rejected cases
plotrej = plot rejected cases (default)
dtsv x = skip all cases w/ ABS(Delta Ts) < x
skip N = skip N FOR's
+ == skip 30 FOR's
goto N = goto FOR #N
home == goto 1
browse = loop through granule without prompting
time = timer in browse = 1 s
?, help = re-print this reminder
FOR= 1 SCAN= 2 FOV= 2 acc dTs=-2.54
HIT RETURN to continue (exit,...,eps,ps) ==> goto 187
FOR= 187 SCAN= 20 FOV=20 REJ dTs=-6.02
HIT RETURN to continue (exit,...,eps,ps) ==> xwd
07:08 AM Mon Oct 20

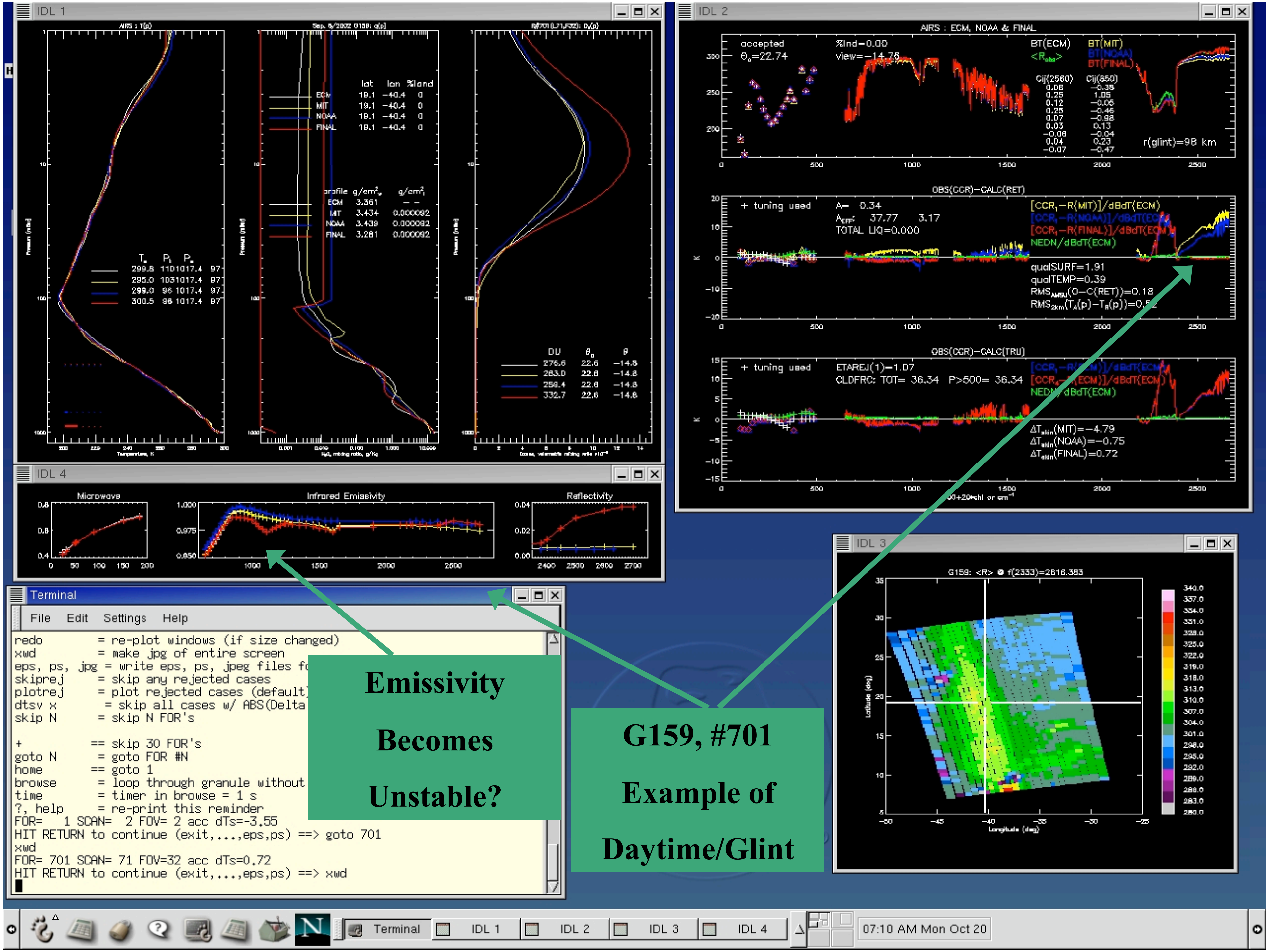


Example of SIMULATION

Same Scene as Before, Now Can Handle These Clouds.

Clouds were OBVIOUSLY frequently over-estimated


IDL 1
IDL 2
AIRS : ECM, NOAA & FINAL
OBS(CCR)−CALC(RET)
OBS(CCR)−CALC(TRU)
IDL 4
Microwave
Infrared Emissivity
Reflectivity
IDL 3
Terminal
File Edit Settings Help
xwd
exit = exit program
redo = re-plot windows (if size changed)
xwd = make jpg of entire screen
eps, ps, jpg = write eps, ps, jpeg files for 4 windows
skiprej = skip any rejected cases
plotrej = plot rejected cases (default)
dtsv x = skip all cases w/ ABS(Delta Ts) < x
skip N = skip N FOR's
+ == skip 30 FOR's
goto N = goto FOR #N
home == goto 1
browse = loop through granule without prompting
time = timer in browse = 1 s
?, help = re-print this reminder
FOR= 1 SCAN= 2 FOV= 2 acc dTs=0.93
HIT RETURN to continue (exit,...,eps,ps) ==> goto 596
FOR= 596 SCAN= 59 FOV=77 acc dTs=0.07
HIT RETURN to continue (exit,...,eps,ps) ==> xwd
G100, #596
Example of
Ocean, NIGHT
Cirrus??
07:09 AM Mon Oct 20


Emissivity Becomes Unstable?
G159, #701 Example of Daytime/Glint
IDL 1
IDL 2
IDL 3
IDL 4
AIRS : ECM, NOAA & FINAL
OBS(CCR)−CALC(RET)
OBS(CCR)−CALC(TRU)
Microwave
Infrared Emissivity
Reflectivity
Terminal
File Edit Settings Help
redo = re-plot windows (if size changed)
xwd = make jpg of entire screen
skiprej = skip any rejected cases
plotrej = plot rejected cases (default)
skip N = skip N FOR's
+ == skip 30 FOR's
goto N = goto FOR #N
home == goto 1
browse = loop through granule without
time = timer in browse = 1 s
?, help = re-print this reminder
FOR= 1 SCAN= 2 FOV= 2 acc dTs=-3.55
HIT RETURN to continue (exit,...,eps,ps) ==> goto 701
xwd
FOR= 701 SCAN= 71 FOV=32 acc dTs=0.72
HIT RETURN to continue (exit,...,eps,ps) ==> xwd
07:10 AM Mon Oct 20

Maybe Existing Indicators Will Remove Some Outliers

- AMSU-Θ(RET) in microwave window channels tend to detect severe cloud clearing problems.
  - This test used to be part of the system, I suggest we revisit its utility.
- CCR-R(MIT) in infrared window channels detects cloud clearing issues.
  - This test could be built into our ETAREJ residual threshold (NOTE: automatic if surface channels are used in cloud clearing).
  - This test is less robust, since MIT and infrared surface state errors can indicate a false rejection.

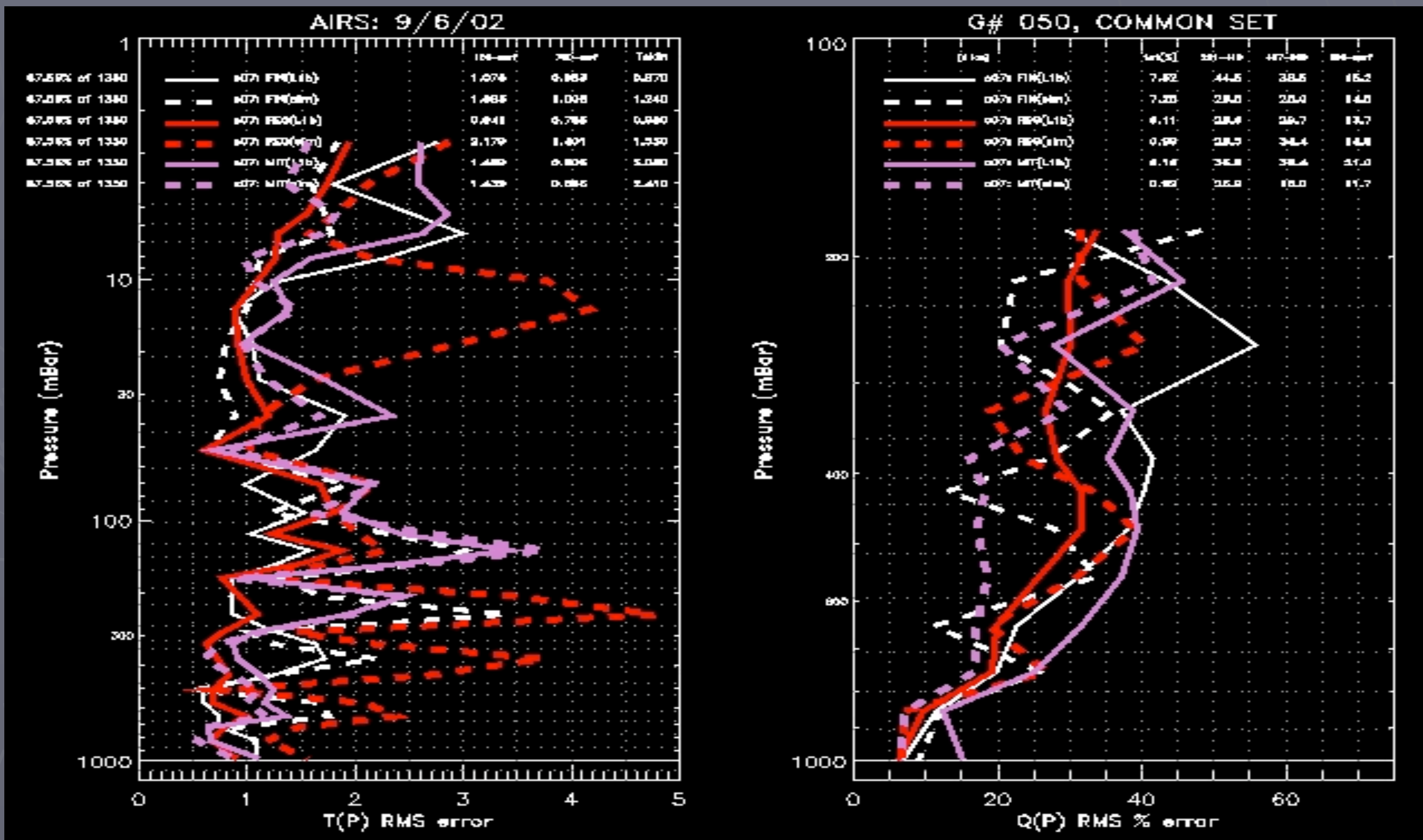
Modification of Existing Quality Indicators May Catch Others

- A_{eff}, a noise amplification estimate that includes both random (amplification) and correlated (errors in eta).
  - On 1st cloud clearing this parameter can detect problems, but it may decrease yield substantially
  - Needs to be combined with other tests.
  - On FINAL step this parameter is contaminated by cancellation of retrieval and cloud clearing errors.
- NOAA_SCORE & Amplification Factor difference
  - Usually these are equal.
  - An indicator of BAD channels within Earth Scene when not equal.

Some New QA Ideas Should be Evaluated

- Apply CLEAR Tests (*e.g.*, George Aumann's CLEAR tests) to CCR's
- CCR-<R>, reject if too much cloud clearing has been done.
- Second pass spatial reasonableness tests to remove errant cases
  - Force retrievals to satisfy thermal wind equation.
  - Force retrievals to satisfy static stability on a large scale (can violate it on small scales).

Comparison of Simulation (vs TRUTH, dashed) and Real Data (vs ESCWF, solid) for Physical (white), Regression (RED) and MIT (Purple)



These Results are Compelling

- MIT statistics are similar (NOTE: real data is tuned, simulated data is not).
- Regression statistics are radically different. Simulated system has vertically oscillating BIAS due to implicit tuning in regression coefficients.
  - Error characteristics are very similar to physical retrieval error (vs. ECMWF) without the error term or tuning.
- Physical algorithm has tendency to "stick" to regression errors in the simulated system (Error term is ON)
  - NO tuning of physical is necessary in simulated system.
  - This makes me question my fg=ECMWF experiments.
  - If the reason these were better is poor performance of physical retrieval, then my conclusions about tuning (at the May STM) were wrong.

Some Retrieval Improvements Need to be Evaluated

- **Tuning**
  - Infrared: Revisit issue after the new UMBC RTA with UMBC transmittance tuning is delivered.
  - Microwave: Utilize Larry's empirical fits to AMSU for SLC issues.
- **Cloud Clearing Issues**
  - CCR-<R> used as an additional CCR error term.
  - Use more window channels to "see" low clouds and detect cirrus/aerosol issues.
  - Blending of MIT and NOAA state when cloud clearing is poor.
    - Initial look at this indicated that it wasn't helpful, but that was based on ensemble statistics within a system with problems.
- **Surface Retrieval Issues**
  - Only solve for one emissivity parameter over ocean (shape preserving).
  - Use additional and more balanced set of channels.
  - Replace SVD with a spectral smoothness constraint.
  - Use gridded emissivity from NOAA NRT AIRS retrievals as a first guess infrared emissivity.
- **Error Term:** Replace ad-hoc values with
  - Physical error estimates (*e.g.*, additional CCR error).
  - Estimates of spectroscopy errors (f/ UMBC).
- Experiment with other retrieval methodologies (*e.g.*, MAP) .

QA and Modifications will be explored at NOAA in the near future

- Within NOAA, the AIRS algorithm is important for
  - A variety of L2 products for NOAA customers.
  - A benchmark for high spectral resolution sounders.
  - The cloud clearing approach will be applied to IASI, CrIS, and possibly GOES/HES.
- NOAA L2 algorithm does NOT have to be equivalent to AIRS science team approach, but
  - A common algorithm has obvious synergistic value.
  - But, NOAA needs a robust, near real-time, L2 product to be available for AIRS soon.
- The NOAA system will need an option to utilize the NCEP GDAS model as a first guess (model background with be retrieval a-priori).

Future Work @ NOAA: Step 1: Build Test Beds

- **Test Bed for statistical evaluation of code modifications**.
  - An ensemble of with representative seasonal, spatial, and problem variability, but it runs quickly (most likely selected scan lines totaling about 20 granules).
  - Mitch's ≈50,000/yr raobs matchup files – need to build preprocessor.
- **Test Bed to Test Retrieval Stability Issues.**
  - Build an ensemble of cases with minimal contamination.
    - JPL produced matchup files of George's single FOV CLEAR cases.
  - Need to build a pre-processor for matchup files.
  - Will require minor modifications of off-line system to run w/o microwave and on a single AIRS FOV rather than a Golfball.
- **Test Bed to Test Global Statistics.**
  - Mitch's Global 3x3^o Gridded Sub-set of complete Golfball is available for ascending and descending orbits on a daily basis since Aug. 2003 (14,400/324,000 Golfballs = 1/22.5 of a day).
  - ECMWF, NCEP AVN, NCEP GDAS are available in same format.
  - Need to build a pre-processor for BINARY grid files.
- **Test Bed of HIGH QUALITY in-situ measurements.**
  - Need to build pre-processor for RTP matchup files.
  - Use Larrabee's RTP files for ARM, TWP, ABOVE, Dome-C.

Future Work @ NOAA
Step 2: Separate the Problem

1) Study Retrieval Stability Issues on cloud filtered FOV's,
   - Eliminates cloud clearing issues
   - Eliminates confusion due to aerosol and cirrus contamination.
   - Ensure retrieval system is stable.
   - Determine required TUNING and ERROR terms (w/ UMBC, Larry).
   - Verify characteristics of system with simulated AIRS radiances.
2) Study Cloud Clearing Ability on Golfball's containing at least one CLEAR FOV
   - Can compare results to single FOV CLEAR results.
   - Utilize visualization tools and simulated Golfballs to understand retrieval stability and QA issues.
   - Contribution to the validation of the cloud clearing algorithm.